VCSELs with a high-index-contrast grating for mode-division multiplexing

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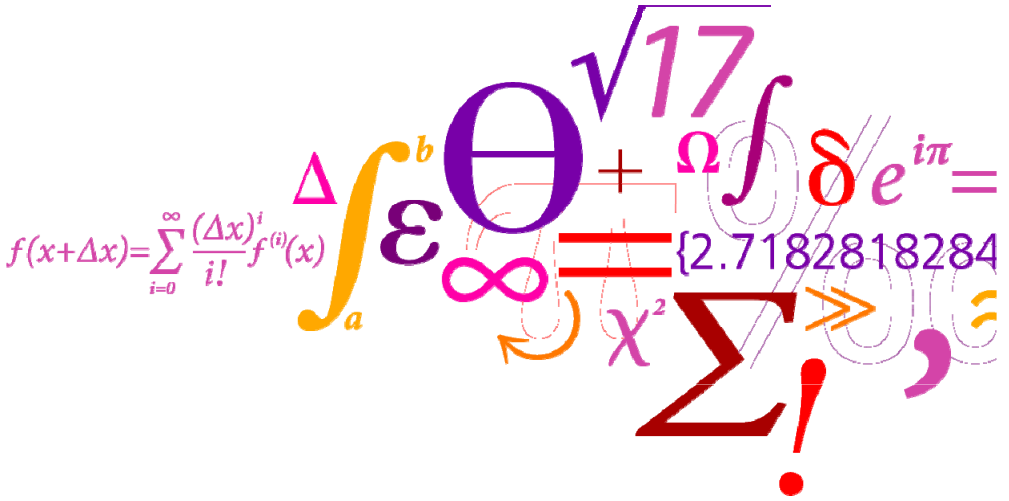
Qijiang Ran and Il-Sug Chung



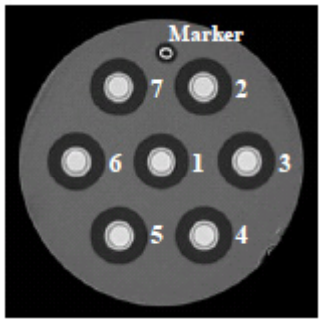
DTU Fotonik
Department of Photonics Engineering

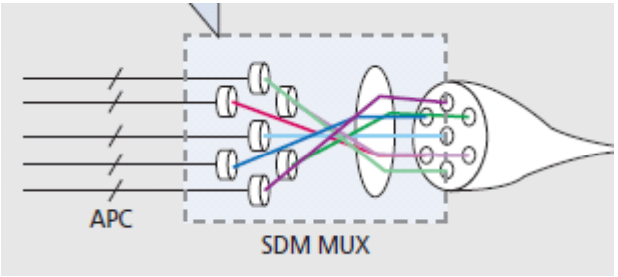
Outline

- Spatial degree of freedom for higher bandwidth
- Prior methods for exciting LP01 modes
- Proposed way: Reflectivity-modulated HCG VCSELs
- Results and discussion
- Summary

Using spatial degree of freedom

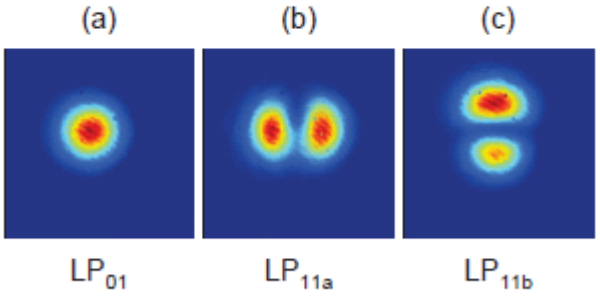
- Space division multiplexing

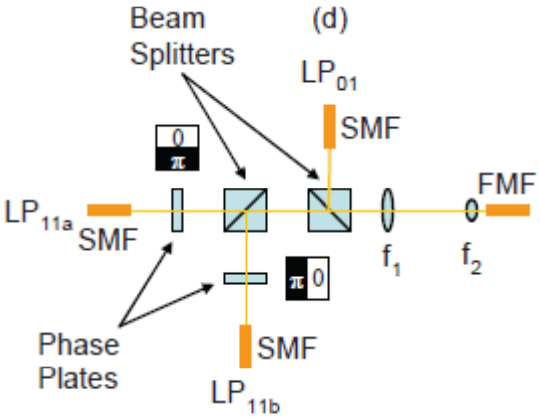




Morioka et al., IEEE ComMag S31 (Feb 2012)
Sakaguchi et al., OFC, PDPB6 (2011)

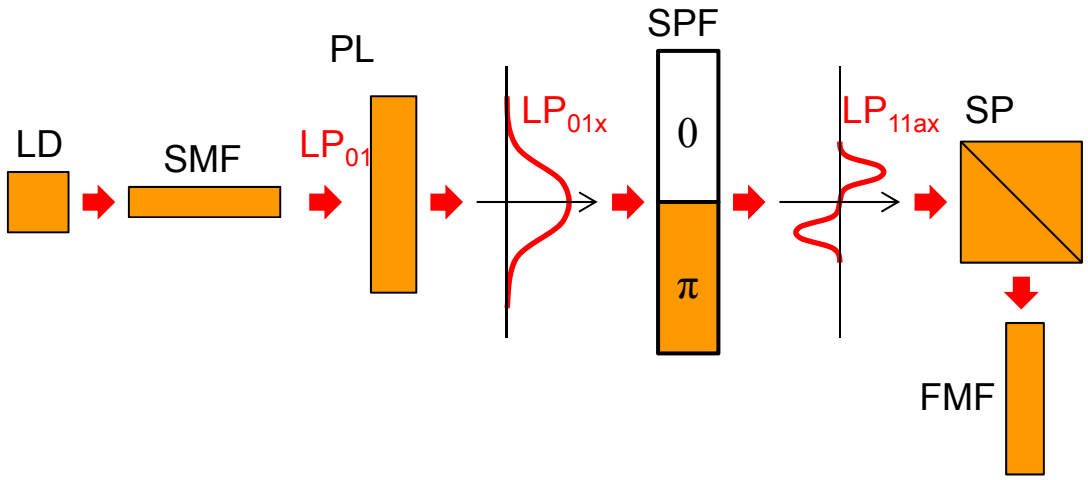
- Mode division multiplexing

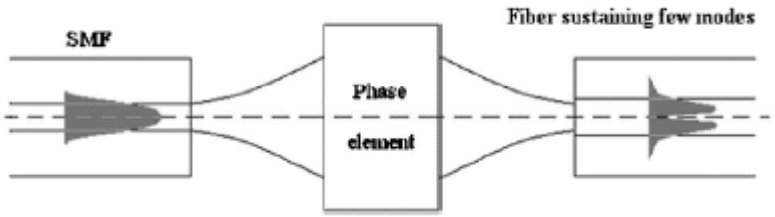




Randel et al., Opt Express **19**, 16697 (2011)

Exciting LP_{11} modes

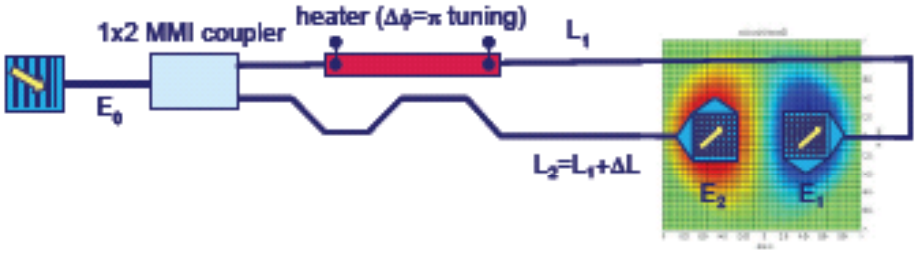




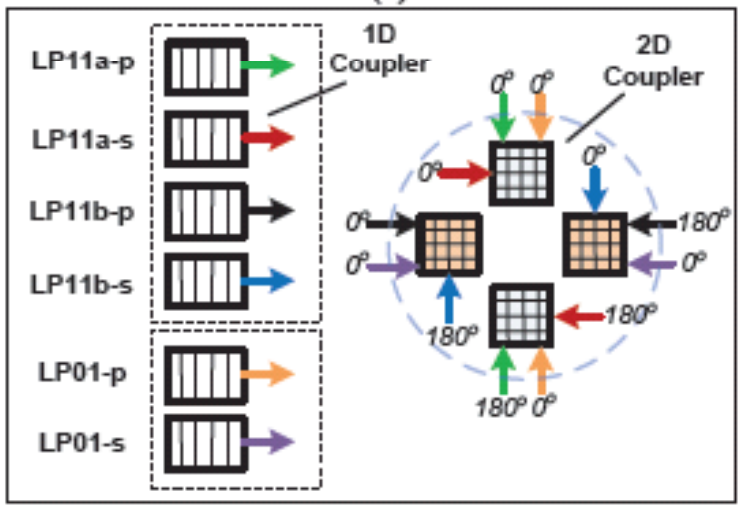
Randel et al., Opt Express **19**, 16697 (2011)

Mohammed et al., Opt Eng **45**, 074602 (2006)

Exciting LP_{11} modes



(b)



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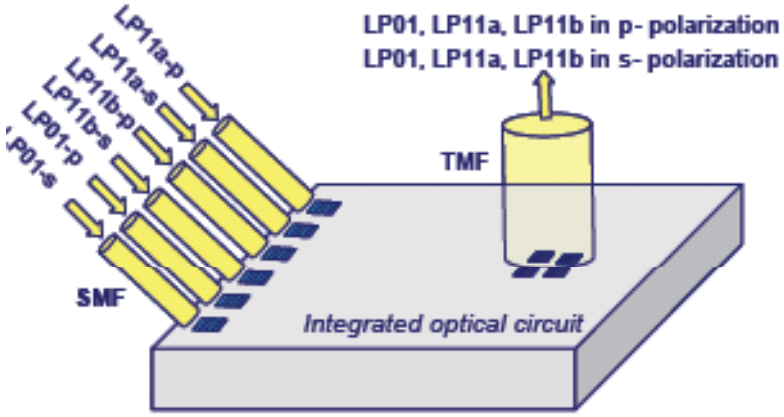
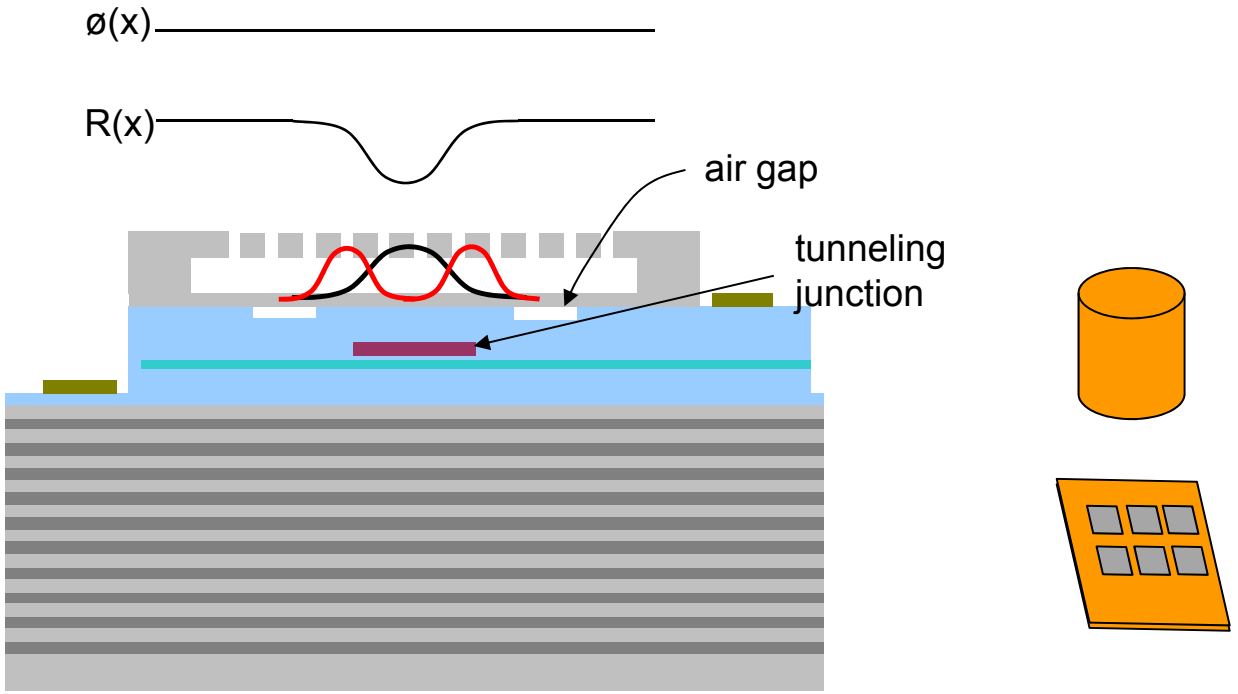


Chen et al., ACP Tech dig, OSA, ATh2B.4 (2012)

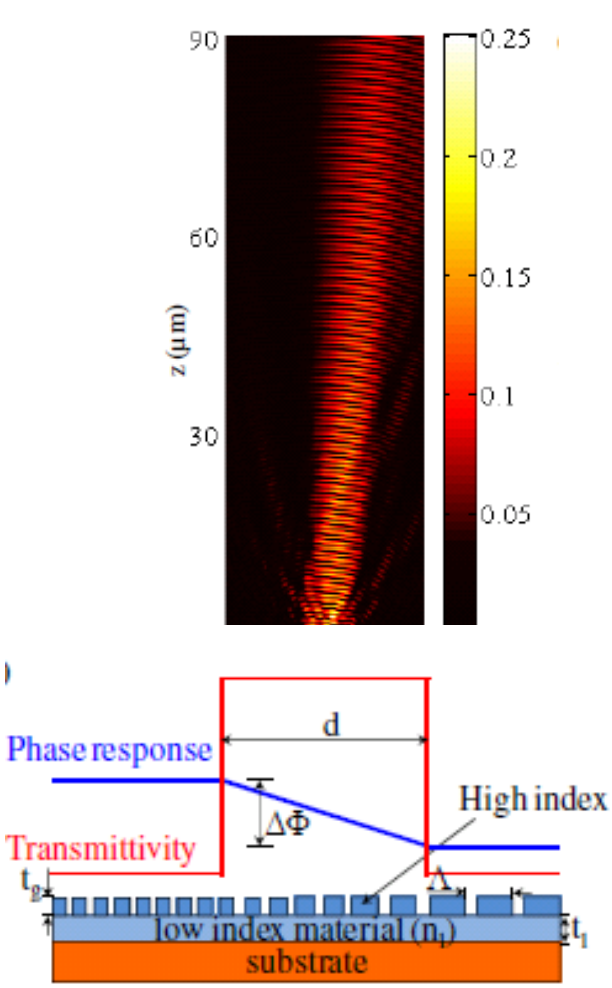
Proposed monolithic approach

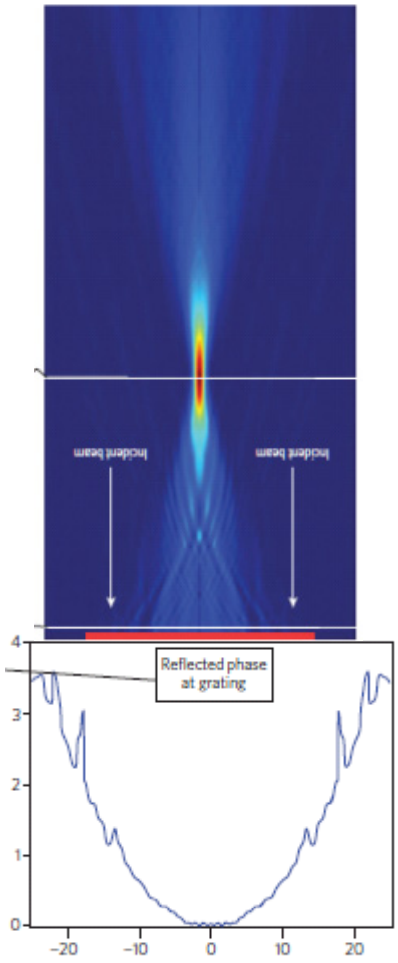


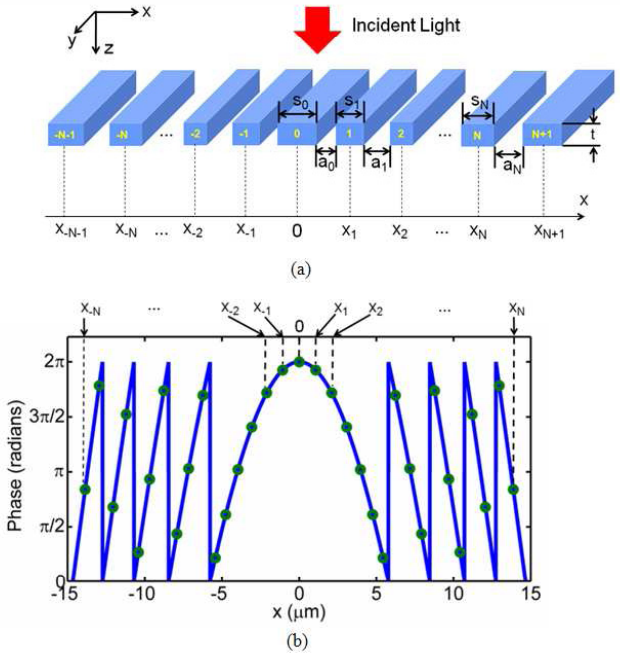
Modulation of phase profile

Engineering phase profile while keeping reflectivity profile constant.

Local phase and reflectivity is determined by local grating parameters.



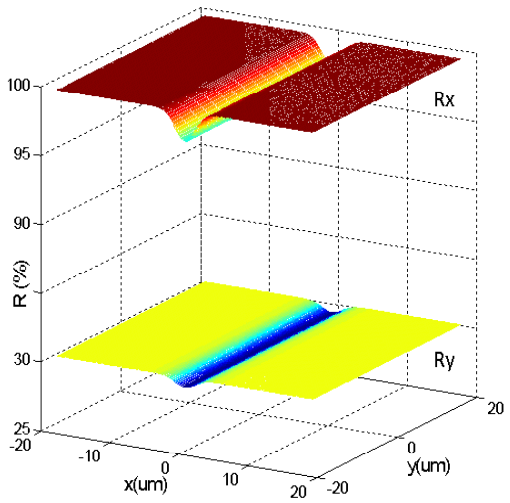


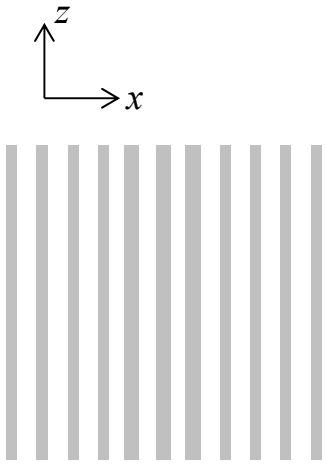


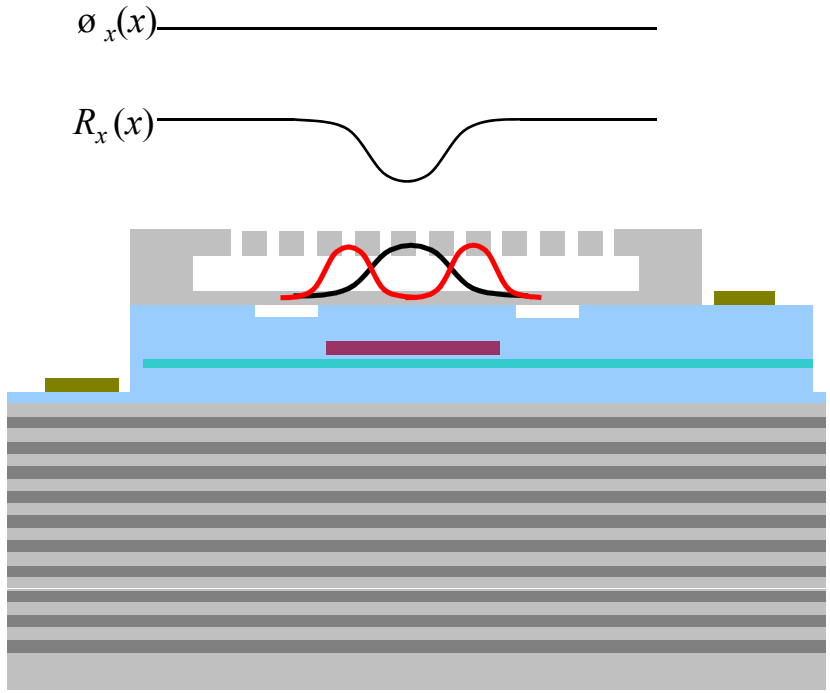
Carletti et al., Opt Express **19**, 23570 (2012).
Fattal et al, Nat Photon **4**, 466 (2011)
Lu et al, **4**, 466, Nat Photon (2011)

Modulation of reflectivity profile

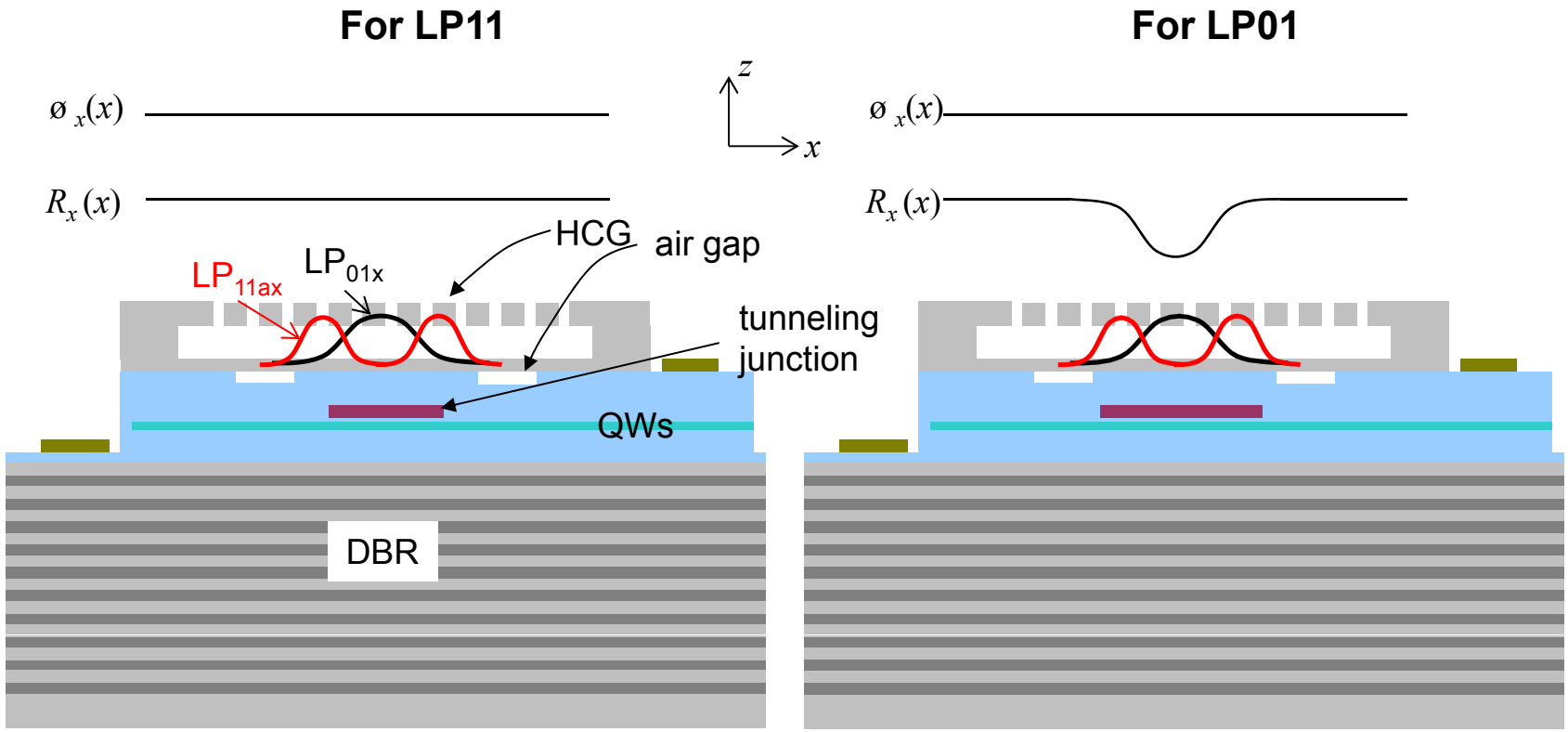
Idea: Controlling local R profile while keeping phase profile.





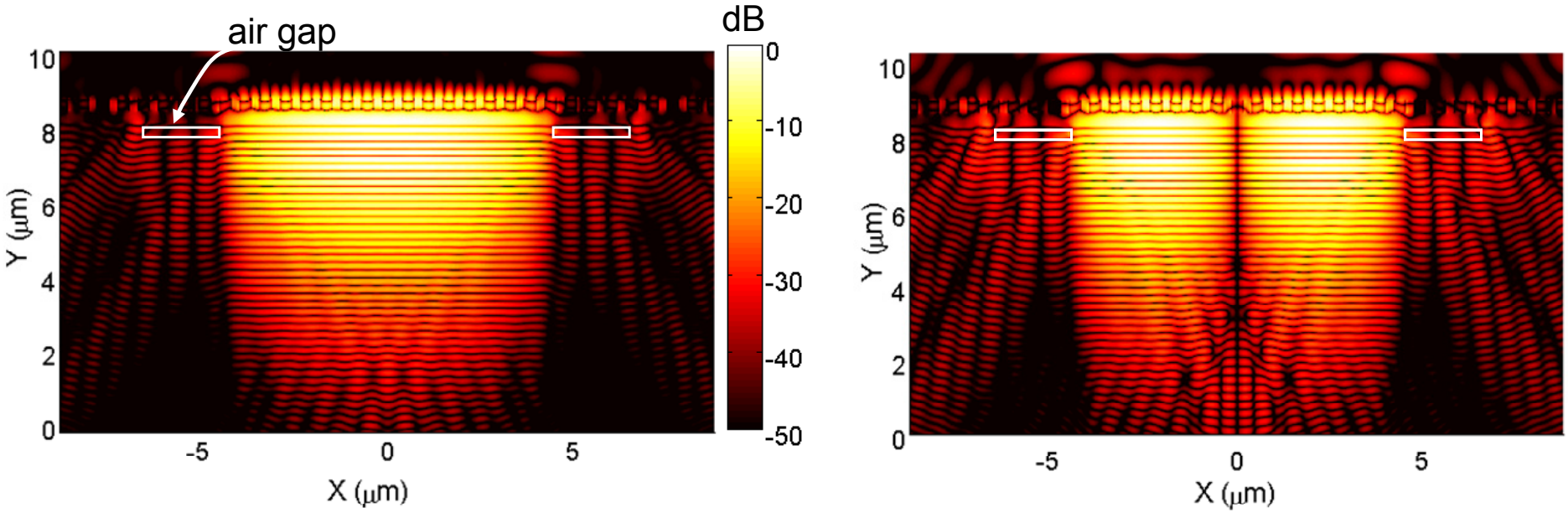


Proposed way

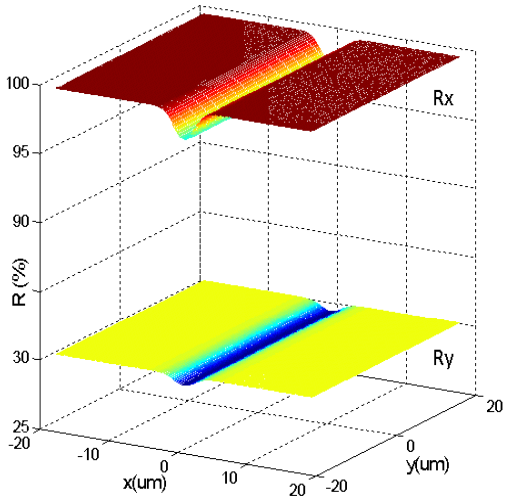


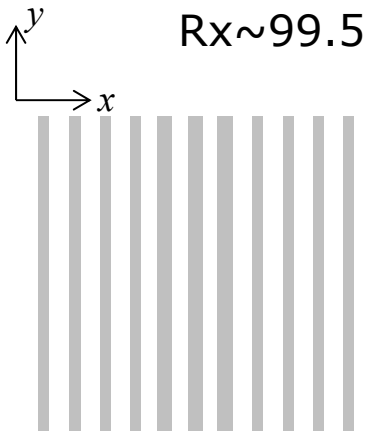
Selective pumping + k-selection

- Strongly enhanced single-mode strength
- 115% (TJ) + 65% (HCG) = 215% (HCG TJ)
- The HCG region is much larger than the optical modes.
- Selective pumping + inherent HCG mode selection brings synergy.

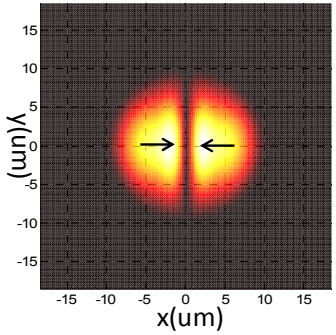


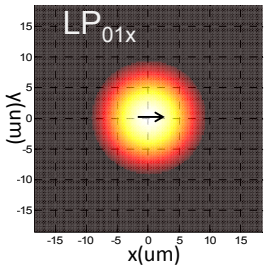
Selecting LP01ax

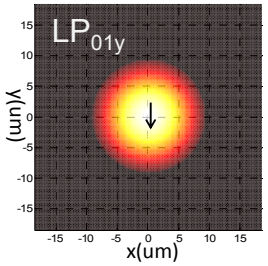


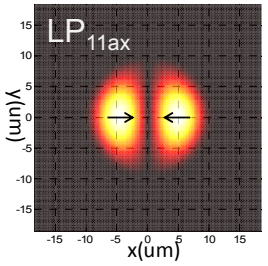


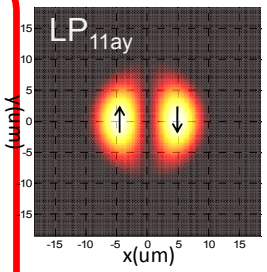
Rx~99.5%, Ry~30%

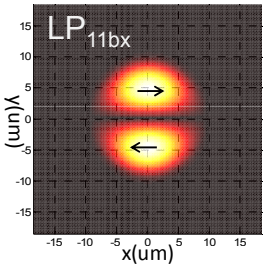


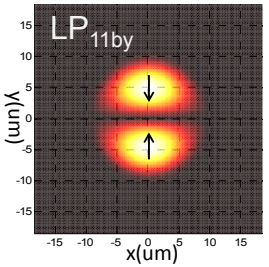










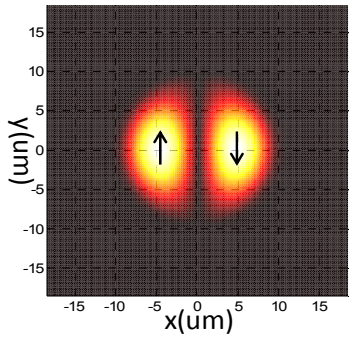


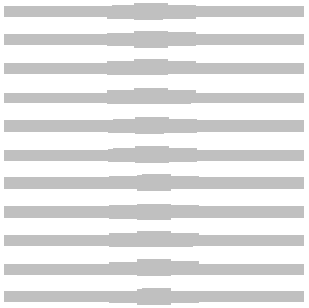
R_{mod}	98.8 %	30.1 %	99.5 %	30.3 %	98.7 %	30.0 %
g_{th}	990 cm^{-1}	73598 cm^{-1}	559 cm^{-1}	73193 cm^{-1}	1052 cm^{-1}	73801 cm^{-1}

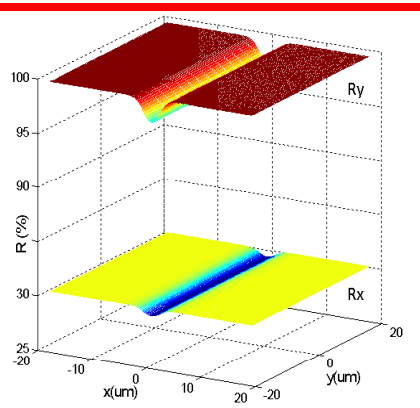
S=77%

Selecting other LP01 modes

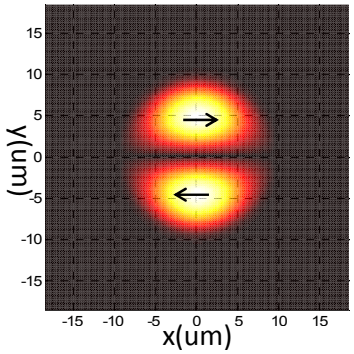
LP_{ay}

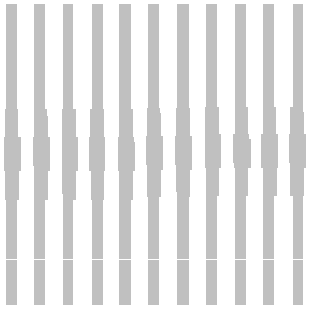


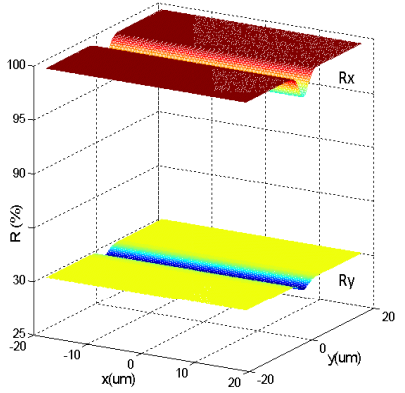




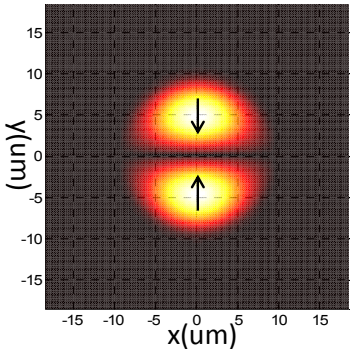
LP_{bx}

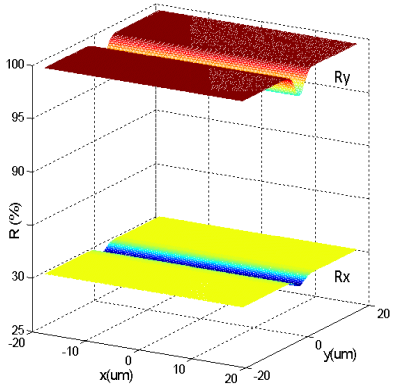






LP_{by}





Summary

- Shaping reflectivity profile of a HCG VCSEL enables to selectively emit LP01 modes
    - Moderate single mode operation for LP01 modes
    - Very strong single-mode operation for LP11 modes
- Possibility of combining beam tilting